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Foraging strategies of the grizzly bear as related to its ecological energetics

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FORAGING STRATEGIES OF THE GRIZZLY BEAR AS RELATED TO ITS ECOLOGICAL ENERGETICS

By

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ABSTRACT

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PREFACE

This thesis was prepared as a manuscript to be published in the Proceedings of the Fifth International Conference on Bear Research and Management.

Approval for presenting the thesis in this manner was based upon the Graduate School's policy of accepting a research paper in lieu of a thesis and my graduate committee's agreement.

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FORAGING STRATEGIES OF THE GRIZZLY BEAR AS RELATED TO ITS ECOLOGICAL ENERGETICS

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Abstract: Four radio-instrumented grizzly bears (Ursus arctos horribilis) were tracked throughout their active season. During this period data were collected, to describe the grizzlies' foraging strategies on home range sizes, movements, and activity patterns. Also, chemical analyses of bear foods were conducted to estimate their nutritional values. Basic energetic formulas were used to assess the energy costs of the individual bears. The home range sizes, movements, and activity patterns used to delineate the individual grizzlies' foraging strategies varied among individuals and by season. The foraging strategies of each grizzly were related to their computed energy costs to better understand the grizzly bear's habitat utilization patterns. Basic habitat management recommendations were made based on the results of the aforementioned procedures.

Key Words: activity, chemical analyses, energetics, food habits, grizzly bear, habitat utilization patterns, home range, Montana, movements, Ursus arctos horribilis.

The "cost of living" for an individual animal, the energy necessary for its life processes, is in accordance with the laws of thermodynamics: the flow of energy through an individual, a population, and an ecosystem is unidirectional and represents an energy budget that must be balanced (Galluci 1973, Lavigne et al. 1976). Consequently, productivity and survival of an animal population are strongly influenced by the ability of its individuals to employ successful foraging strategies. The study of ecological energetics, the energy costs of animal populations, and how these costs are met by the animal have played an increasingly important role in wildlife research (Moen 1973, Mautz 1978).

The overall objective of this study was to examine the foraging strategies of the grizzly bear (Ursus arctos horribilis) and thereby to better understand how these processes function to meet its energy costs. The specific objectives to accomplish the above were threefold:

1. describe the foraging strategies for a sample of grizzly bears of differing population classifications by (a) measuring and delineating their home range sizes, movement, and activity patterns, (b) inferring the nutritional value of their food sources, and (c) integrating these parameters with the results from other University of Montana Border Grizzly Project (BGP) studies;

2. describe the energy costs of the sampled bears based on the time of year and on their age, sex, weight, and reproductive condition; and
3. contrast and relate the energy costs of the sampled bears to their delineated foraging strategies.

I wish to thank the various sponsors of this study: the U.S. Fish and Wildlife Service (Denver Laboratory), the Montana Department of Fish, Wildlife and Parks, the University of Montana School of Forestry (McIntire-Stennis funds), the U.S. Forest Service, the Wildlife Management Institute, and the University of Calgary (a Parks Canada grant). In particular, Dr. Steve Herrero (University of Calgary); John McIvor and Robert Hensler (U.S. Forest Service); University of Montana graduate students Pete Zager and Patsy Martin; and BGP volunteers and employees Rick Mace, Tim Bumgarner, Sally Duff, John Bevins, Kevin Cooper, Davy Gillespie, and Harry Carriles, and Wildlife Biology Program Secretary Karen Kaley provided excellent and important aid. I am especially grateful to Dr. Charles Jonkel, my major adviser, for the opportunity to do this study and for his support throughout.

METHODS

Field Data Collection and Analysis

This study was initiated in the South Fork of the Flathead Study Area (Joslin et al. 1977) as part of a

long-term research effort by the University of Montana Border Grizzly Project (BGP 1976). As a result of a capture-recapture program (Joslin et al. 1977), four radio instrumented grizzly bears of various age and sex classifications were available for continuous radio-tracking (Telonics, Telemetry-Electronics Consultants, 1048 East Norwood, Mesa, AZ). Therefore, during 1979, collecting a full field season of data simultaneously for each of the four bears was possible. Table 1 contains the dates of capture and instrumentation, and the age, sex, and weight information for the radio instrumented bears.

Home Ranges and Movements

Home range and movement data were collected using both aerial and ground radio-tracking techniques, with 85% of the specific locations being achieved by ground efforts utilizing triangulation techniques. At the end of each tracking period, specific radio locations were plotted on study area base maps (scale: 3.3 cm = 1 km). Annual and seasonal home ranges were computed using the minimum and modified minimum techniques (Mohr 1947, Harvey and Barbour 1965) for graphical purposes, and the bivariate model method (Jennrich and Turner 1969) for area determinations. Seasonal designations for the categorization of bear movements were spring-summer (den emergence to July 31) and summer-fall (August 1 to den entry), based on major food habit

Table 1. Bear age, sex, weight, and capture information for bears radio-tracked in the South Fork of the Flathead River (Montana) study area.

Bear Number	Age[1]	Sex	Capture Date	Weight (Kg)[2]
297[3]	9.5	F	10-18-78	136
363[4]	4.5	F	6-26-79	70
395	5.5	M	6-29-79	54
114	7.5	M	6-22-79	113

[1]Ages are for 1979 field season.

[2]Weights are at time of capture.

[3]Bear no. 297 had three cubs of the year during the 1979 field season.

[4]Bear no. 363 showed signs of esterous at time of capture.

differences (e.g. spring-summer--herbaceous plant material; summer-fall--berries) (Mace and Jonkel 1980).

Even though the bivariate procedure is known to over-estimate home range rize, it was used for this study because it is considered unbiased when sample size is unequal and should therefore best facilitate comparisons between individuals. Ellipes for the bivariate procedure were computed on the University of Montana DECSYSTEM-20 computer using a basic program and the formulas developed by Jennrich and Turner (1969). To compare seasonal movement patterns between individual bears, linear distances between consecutive days (Amstrup and Beecham 1976) were measured from the plotted specific radio locations. The Wilcoxon two-sample test (Sokal and Rohlf 1969) was used to test for significant differences between the movements. Linear and mean daily distances were graphed to illustrate and depict movement patterns.

Activity Patterns

Activity data were also collected using radio telemetry. When a bear was located, BGP personnel monitored the animal for as long as the bear was accessible. Whenever possible, bears were monitored for 24-hour periods.

Bear activity can be recorded through interpretation of the integrity of the radio signal (Poelker and Hartwell 1973, Amstrup and Beecham 1976, Lindsey and Meslow 1976).

However, radio interference, temperature fluctuations, and slight movements by the bear inhibit accurate activity determinations (Garshelis and Pelton 1978 and 1980). Lindsey and Meslow (1976), using this method in conjunction with radio locations and direct observations, found it to be biased toward activity to such a degree as to preclude its usage. Furthermore, Rogers (1977) stated that during aerial tracking bear activity could not be determined using the integrity of the radio signal. Other methods for measuring activity such as the use of strip chart recorders were not used for this study because of their required calibration, awkwardness, and expense (Gilmer et al. 1971, Varney 1973). The most reliable and accurate technique of interpreting bear activity is through the use of transmitters equipped with activity-sensing monitors (Garshelis and Pelton 1978).

For the purposes of this study, activity was recorded only when a change in location by a bear was of enough magnitude to be determined by triangulation. Bears were recorded as stationary during periods when no movement was determined. Recordings made during any portion of an hour were assigned to the nearest whole hour. Admittedly, this method underestimates activity by its lack of sensitivity between radio locations. However, this bias was considered consistent from one location and/or bear to another, thereby

producing qualitatively comparable data. To graphically display activity patterns, probabilities of activity (Garshelis and Pelton 1980) were computed and plotted. The sign test (Mosteller and Rourke 1973) was used to statistically compare these probabilities.

Bear Foods

Plant material has been found to compose the major portion of the grizzly bear's diet (98%) in the South Fork Study Area (Mace and Jonkel 1980). To further describe grizzly foraging strategy, grizzly food plants were collected and chemically analyzed to infer their nutritional values. Plants were collected on sites recently utilized by grizzly bears as determined by observations of feeding sign. On such sites, collections were made of the phenological stages and portions of the plants selected by the bear. Also, for comparative purposes, the phenological stages and portions not selected by the bear were collected. The collected foods were analyzed for percent cell and cell wall content according to the methods outlined by Goering and Van Soest (1970). The major constituents of the cellular contents--percent proteins, fats, and total available carbohydrates--were determined utilizing the procedures of Black (1965), American Organization of Analytical Chemists (1970), and Smith et al. (1964), respectively.

The cellular contents of plants are considered 98%

digestible for monogastric animals. However, the utilization of the cell wall (the structural carbohydrates, cellulose, and hemicellulose) is limited without the process of microbial fermentation (Van Soest 1967). The monogastric stomach of the bear is too acid to support microorganisms (Rogers 1976), and, unlike other monogastric herbivors, its digestive tract lacks a cecum that functions as a suitable environment for microorganisms (Frandson 1974). However, it may be that like man (Van Soest 1978) the grizzly has microbial populations in the lower digestive tract sufficient enough to digest the cell wall constituents, cellulose and hemicellulose, of certain fruits and vegetables (i.e., apples, potatoes, carrots). These microbial populations, however, are insufficient to significantly digest the cell wall portion of forage material (Van Soest 1978). It is likely, then, that those bear plant foods of similar cell structure digestible by man are equally digestible by the bear--foods such as the roots and bulbs of Lomatium spp., Erythronium grandiflorum, and Claytonia lanceolata, and the berries of Vaccinium spp., Ribes spp., Sorbus spp. etc. (Van Soest, pers. comm.).

The cell content analysis was chosen to estimate the percent of the plants readily digestible. The cellular constituents were chosen because they provide the most readily available source of digestible energy for the bear. The protein analysis was conducted by Timothy Bumgarner

(BGP); all other analyses were completed by the Range Science Laboratory, Colorado State University, Ft. Collins.

To facilitate comparisons, nutritional indices (NAI) (Kleiber 1975, Van Soest 1967) were computed to estimate the metabolizable energy content of the sampled plants utilizing the following formula:

$$NAI = (.98((\%P - 7\%) \times 4) + (\%C \times 4) + \%F \times 9)) / 100$$

where:

NAI = nutritional availability index for metabolizable energy (kcal per gram of dry weight forage)

0.98 = digestibility constant for cellular constituents

% P = percent protein of plant sampled

7% = constant for amount of undigestible protein contained in the lignin fraction of the cell wall (Van Soest 1967)

% C = percent total available carbohydrates of plant sampled

% F = percent fats of plant sampled

4,4,9 = constants for converting percent chemical compositions to metabolizable kcal (Pike and Brown 1975)

100 = conversion factor - kcal/100g to kcal/1g

If indeed the bear is capable of digesting the cell wall constituents of berries, roots, and bulbs, however,

the nutritional availability-index formula underestimates the value of these plants.

Energy Cost Estimation

The energy costs for each of the radio-instrumented grizzly bears were assessed on the basis of season, age, weight, and reproductive condition. Because precise, quantitative assessment of energy costs was not possible, due to the lack of empirical data, theoretical energetic formulas were used to estimate the energy costs of the individual bears. Descriptions of the formulas and the necessary assumptions made for their use follow.

The energy costs of Basal Metabolism, the energy necessary to maintain vital cellular activity, respiration, and circulation; Maintenance Metabolism, the energy necessary for voluntary activity to maintain a non-producing animal at a constant weight; and Production Metabolism (fat and lactation production costs are dealt with only), the energy necessary to carry out production activities, were assessed for each animal by the previous seasonal designations. For the energy formulas, den emergence was assumed to be May 1 and den entry October 31. The energy cost estimates are expressed in kcal/24 hours or kcal/ seasonal period.

Basal Metabolism (BM) was estimated using Kleiber's (1975) equation for mammals:

$$BM = 70 \times W^{.75} \quad (1)$$

where BM is measured in kcal/24 hours and W equals body weight in kg. Hock (1957) reported that the basal metabolism of the black bear corresponded with Kleiber's equation.

Maintenance Metabolism (Ma) was calculated using the multiple factor 1.4 for omnivores (Crampton and Harris 1969) where:

$$Ma = 1.4 \times BM \quad (2)$$

The energy costs of individual activities (i.e., running, foraging, walking, etc.) (Moen 1973) were not evaluated in this study because of the low sensitivity of the method employed to collect activity data.

The total maintenance energy costs (TMec) of the spring-summer period for all bears except female No. 297 were estimated by the equation:

$$TMec = \sum_{i=i}^{n} (1.4 \times 70 \times Wi^{.75}) \quad (3)$$

where n equals the number of days in the time period (87 spring-summer days). For the spring-summer period it was assumed that no weight was gained or lost. All age and sex classes of Idaho black bears (Ursus americanus) (J. Beecham unpublished data) experienced weight loss, particularly females with young, or maintained their weight during the spring-summer period, except for older males which showed slight weight gains.

Because a female, No. 297, was captured on 19 October

1978, her fall weight was evaluated to estimate her den emergence weight, and an appropriate weight was thereby obtained to compute her spring-summer energy costs. This was accomplished by mathematically calculating her denning period weight loss due to the energy costs of hibernation and lactation. The hibernation costs (Hc) were estimated by the equation:

$$Hc = W_f \times .25 \qquad (4)$$

where Hc equals weight lost in kg and .25 equals the percent lost in the den (Johnson et al. 1978, Folk et al, In Press, Kingsley et al. In Press). The energy cost of lactation was measured using the formula of Lavigne et al. (1976) adapted from Moen (1973), assuming that the quantity of milk produced is equivalent to the energy demands of the young:

$$TMp = \frac{A + CI + 2 \times 70\ Wi^{.75}}{E} \qquad (5)$$

In this formula, TMp equals total milk production, and A equals the activity increment of the young (assumed to be 0 in the den). GI equals 0.85, and is a growth efficiency increment expressed in energy units (kcal/day) (Moen 1973) based on a weight at birth of 0.5 kg (Mundy 1963) and a growth rate of 0.058 kg/day computed from the capture information of Pearson (1975) and Mundy (1963). Lacking empirical data on the energy assimilation characteristics of bear cubs, the variable GI was manipulated to produce a result similar to the weight loss pattern for females

reported by Kingsley et al. (In Press), i.e., females lose from 20 to 40% of their body weight in the den. Kingsley was unable to calculate separate weight losses for females with young; therefore, the 40% figure was chosen as a model for the preceding formula based on the assumption that lactating females would lose the greatest amount of weight.

The $2 \times 70\ Wi^{\cdot 75}$ portion of the equation is an estimate of the basal metabolism for a cub, assuming a higher rate by a multiple of 2 for very young animals (Lavigne et al. 1976), and E is the net energy coefficient for milk production assumed to equal 0.8 (Moen 1973).

To estimate the total milk production for the denning period, a summation was done by starting Wi equal to 1 at 0.5 kg and incrementing by the growth rate 0.058, by the number of days the cubs are in the den. Assuming a birth date of January 1, n equals 125 days. To convert TMp to energy cost of production (TMpc), milk production was multipled by the constant 1.6 (Crampton and Harris 1969):

$$TMpc = 1.6 \times TMp \ . \qquad (6)$$

Because female No. 297 had three cubs and the energy costs for multiple young are not strictly additive, the energy costs for milk production to meet the demands of three young were estimated by the following formula (Moen 1973):

$$TMpc_3 = TMpc \times 2.5 \ . \qquad (7)$$

The factor 2.5 was also manipulated to approximate the weight loss reported by Kingsley et al. (In Press). Using

the method of Lavigne et al. (1976) $TMpc_3$ was converted to kg of fat loss (FL) using the formula:

$$FL = TMpc_3 / 9000 \qquad (8)$$

where 9000 equals the conversion factor of kcal to kg of fat (Crampton and Harris 1964). The total weight lost (TWL) by female bear No. 297 during the denning period due to lactation and hibernation costs equals:

$$TWL = W_f - (H_c + FL) . \qquad (9)$$

The lactation cost of female No. 297 for the spring-summer period was estimated using formulas (5), (6), and (7). The activity variable (A) in formula (5) was assumed to equal 1.4 (Crampton and Harris 1964). The cub growth rate variable increased from 0.058 for the denning period to 0.230 kg/day for the spring-summer period (capture information--Mundy 1963, Pearson 1975). Foraging by the cubs, therefore, was assumed to supply the energy necessary for this additional growth. The value of GI for the denning period consequently was used for the spring-summer period, as was the denning growth rate (0.058), to calculate the daily weight gain for the Wi summation. Since milk production was assumed to have decreased during this period, as compared to the denning period, the multiple factor 2.5 of equation (7) was lowered to 1.5. This variable was also manipulated to best approximate the 70% annual weight recycling figure for adult females by Kingley et al. (In Press).

The initial spring-summer weight used for the subsequent

formulas was calculated from the results of equation (9) minus the fall capture weight of female No. 297 (Table 1). Equation (8) was employed to estimate the weight loss for female No. 297 during the spring-summer period. A daily increment of weight loss was computed (results of equation (8), divided by the number of days of the spring-summer period). I then used formula (3) and summed the total with the results of formula (7) to estimate the total spring-summer energy costs of female No. 297. Foraging by female No. 297 was assumed to supply only the necessary energy for maintenance and the additional energy for lactation was supplied by her body fat.

The total maintenance energy costs (TMec) of the summer-fall period were estimated for each bear using equation (3). Incrementation of the Wi variable was done to increase the weights for bears Nos. 114, 363, and 395 by 25%. The figure 25% represents the necessary weight gain for winter hibernation maintenance computed by altering equation (4) as follows:

$$Hwgi = Wss \times .25 / n \qquad (10)$$

where Hwgi equals the weight gain increment to increase the spring-summer weight by 25%, Wss equals the weight of the bear at the end of the spring-summer, and n equals the number of days in the summer-fall period. The fat accumulation production costs (Fpc) during this period were calculated using the formula:

$$Fpc = Wga \times 9000 \qquad (11)$$

where Wga equals the weight gained for the summer-fall period.

Data from Beecham on black bears in Idaho (Pers. Comm.) describes weight gains by subadult males and females and adult males that may be in excess of the required hibernation weight gain. Therefore, my computed fat production costs are perhaps underestimates. The older male, bear No. 114, was recaptured on 10 October 1979 and had gained 45kg or 39% over his spring-summer weight. His weight gain was also used to compute an estimate of the energy necessary for this gain.

Total energy costs for the summer-fall period (TECsf) were computed by summing the results of equation (3) with those of equation (11).

$$TECsf = MEC + Fpc \qquad (12)$$

The total maintenance energy costs of female bear No. 297 was calculated using equation (3). Incrementation of the Wi variable was of a magnitude necessary to replace the weight lost during the denning and spring-summer period, computed by summing the results of equations (8) and (4) and dividing by the number of days of the summer-fall period.

The fat production costs of female No. 297 were estimated using equation (11) where Wga equals the summed results of the above calculations of equations (8) and (4).

The total energy costs of female No. 297 were calculated using equation (12). This calculation may overestimate the ability of a female with cubs to replace weight lost through lactation and denning in that females with cubs of the year may not enter the den weighing as much as when they entered the previous year (Beecham 1980). Lactation was assumed to have stopped during the summer-fall period. Servheen and Lee (1979) reported that grizzly females accompanied by young of the year were not lactating by October. Pearson (1975), however, reported lactation still occurring in females accompanied by yearlings, and Hensel et al. (1969) reported females with yearlings to be lactating at levels lower than females with cubs of the year. R. Hugie (Pers. Comm.) stated that Maine black bears may or may not be lactating during the fall months, depending upon the quality of the habitat in a given area and the quantity of food production during any given year. He further stated lactation continued longer in lower quality habitat and during poorer food producing years.

Each of the computed energy costs was transformed to express relative energy costs per kg of body weight by dividing the costs by the individual weights.

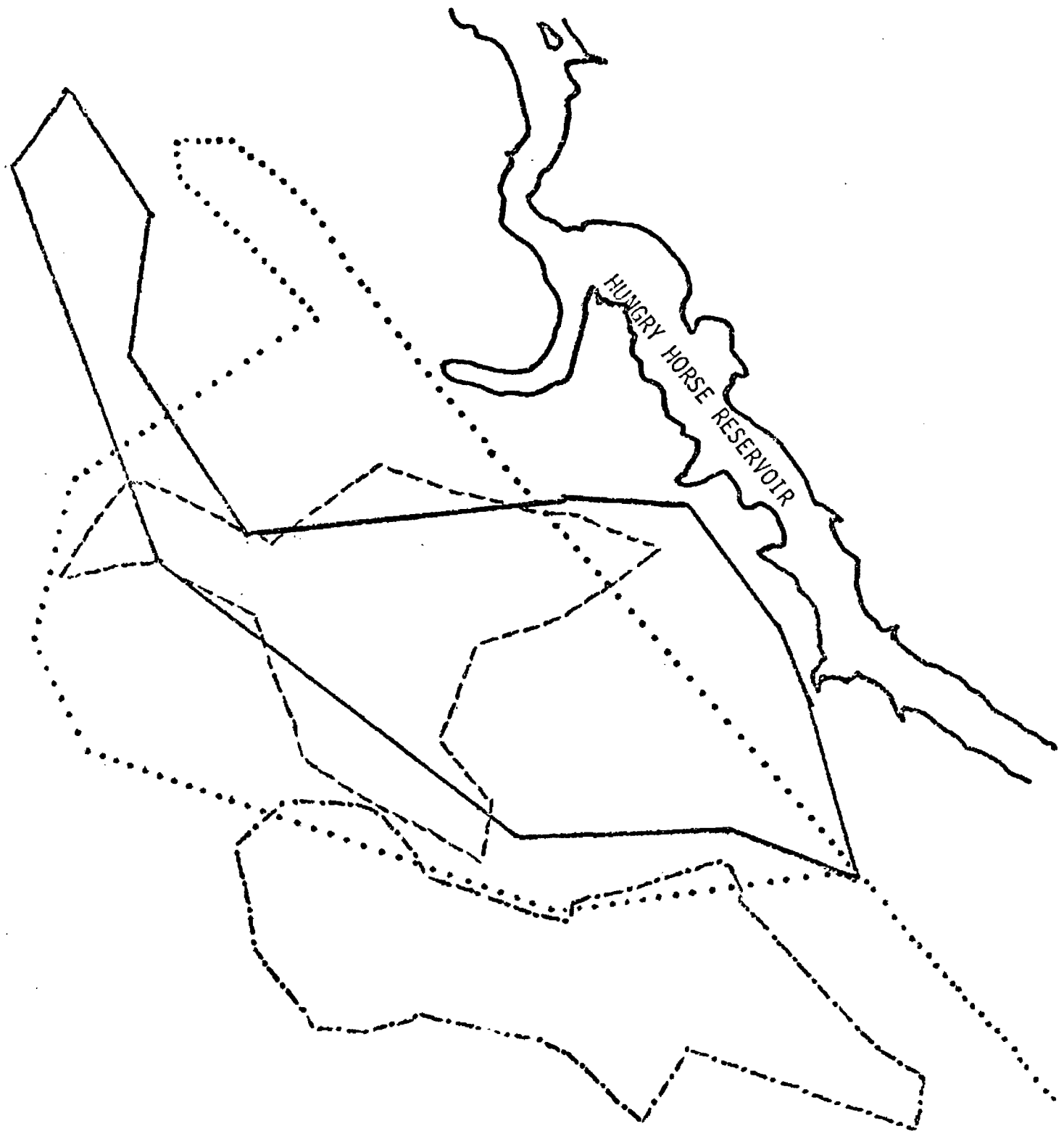
RESULTS

Home Ranges and Movements

The annual, minimum, graphical representations (Fig. 1)

of the home ranges indicate a considerable spacial overlap for the three bears, Nos. 114, 395, and 363. Only the home range of female No. 297 and her three cubs is separated from the other bears. Seasonal home ranges and radio location points are presented in Figures 2-5. The computed elliptical home range areas and radio location sample sizes are contained in Table 2. The spring-summer home range area of female No. 297 and her three cubs was half the size of those of the other bears, which were essentially equal to one another. During the summer-fall period female No. 297 again had the smallest home range, and the older male, No. 114, had the largest home range. The home range areas of the two younger bears, Nos. 363 and 395, were similar to one another and intermediary to the other bears. The summer-fall ranges of all bears were larger than the ranges of the spring-summer period.

Movements for each animal in terms of mean distance traveled per day are displayed graphically in Figure 6. During the spring-summer period, the movements of the older bears, Nos. 114 and 297, were not significantly different. The movements of both bears were significantly greater (at the 0.01 level) than the movements of the younger bears, Nos. 363 and 395. During this same period, the movements of Nos. 363 and 395 were not significantly different from each other. For the summer-fall period, the movements of female No. 297 were significantly smaller



FEMALE BEAR NO. 297

MALE BEAR NO. 395

FEMALE BEAR NO. 363

MALE BEAR NO. 114

FIGURE 1. ANNUAL HOME RANGES OF 4 RADIO INSTRUMENTED BEARS TRACKED DURING THIS STUDY IN THE SOUTH FORK OF THE FLATHEAD RIVER.

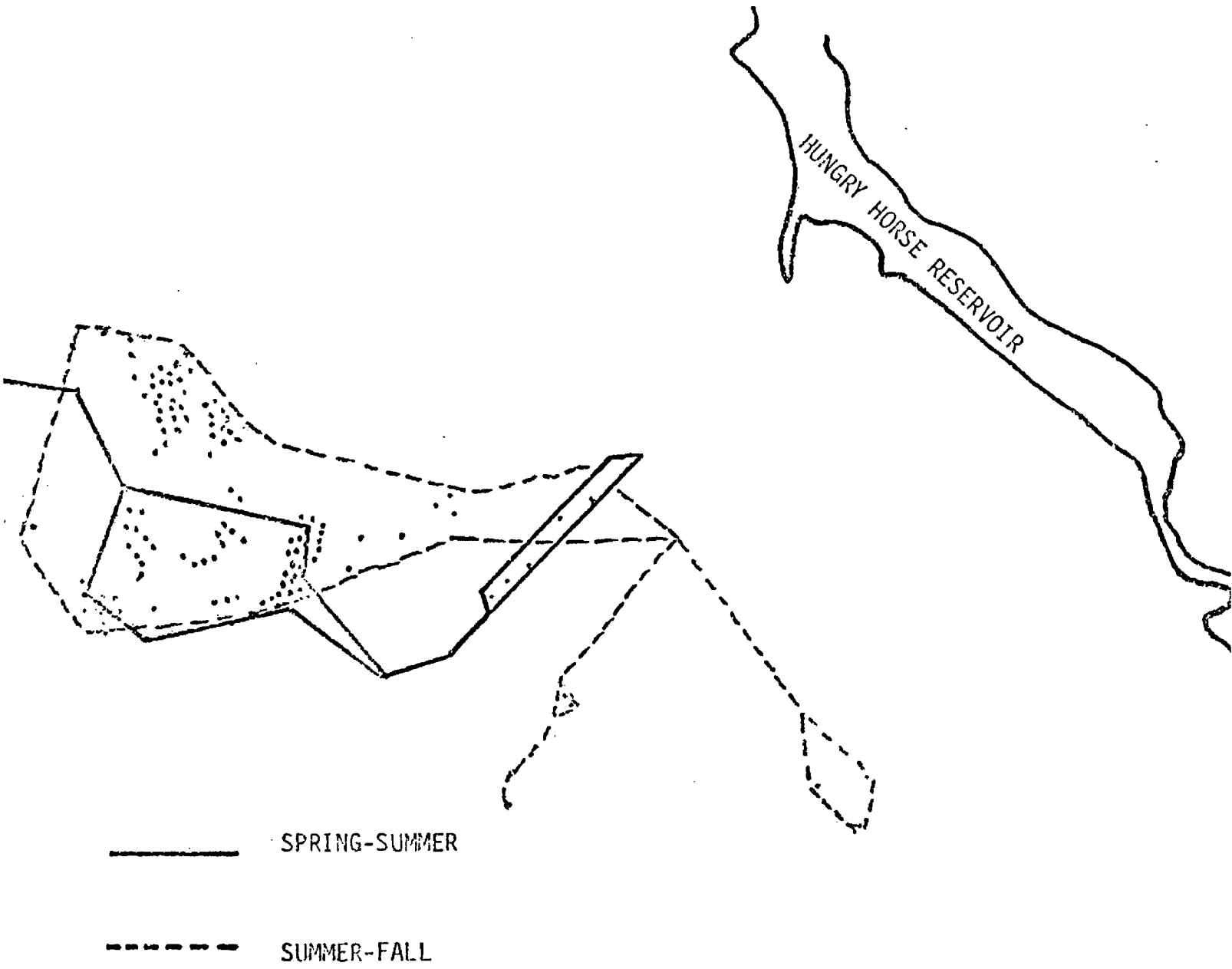


FIGURE 2. SEASONAL HOME RANGES OF FEMALE GRIZZLY BEAR NO. 297, SOUTH FORK OF THE FLATHEAD RIVER, 1979.

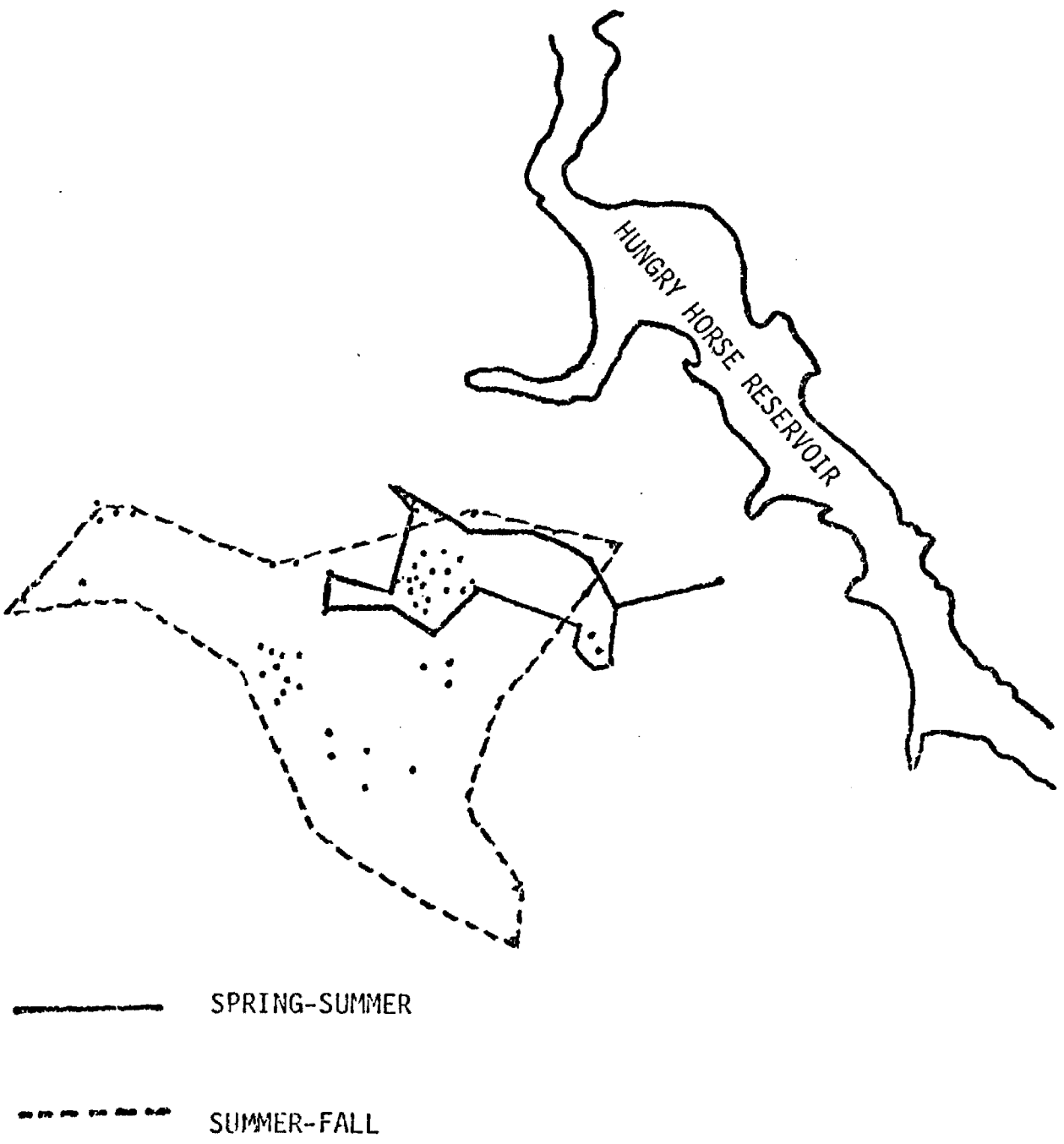


FIGURE 3. SEASONAL HOME RANGES OF FEMALE GRIZZLY NO. 363, SOUTH FORK OF THE FLATHEAD RIVER, 1979.

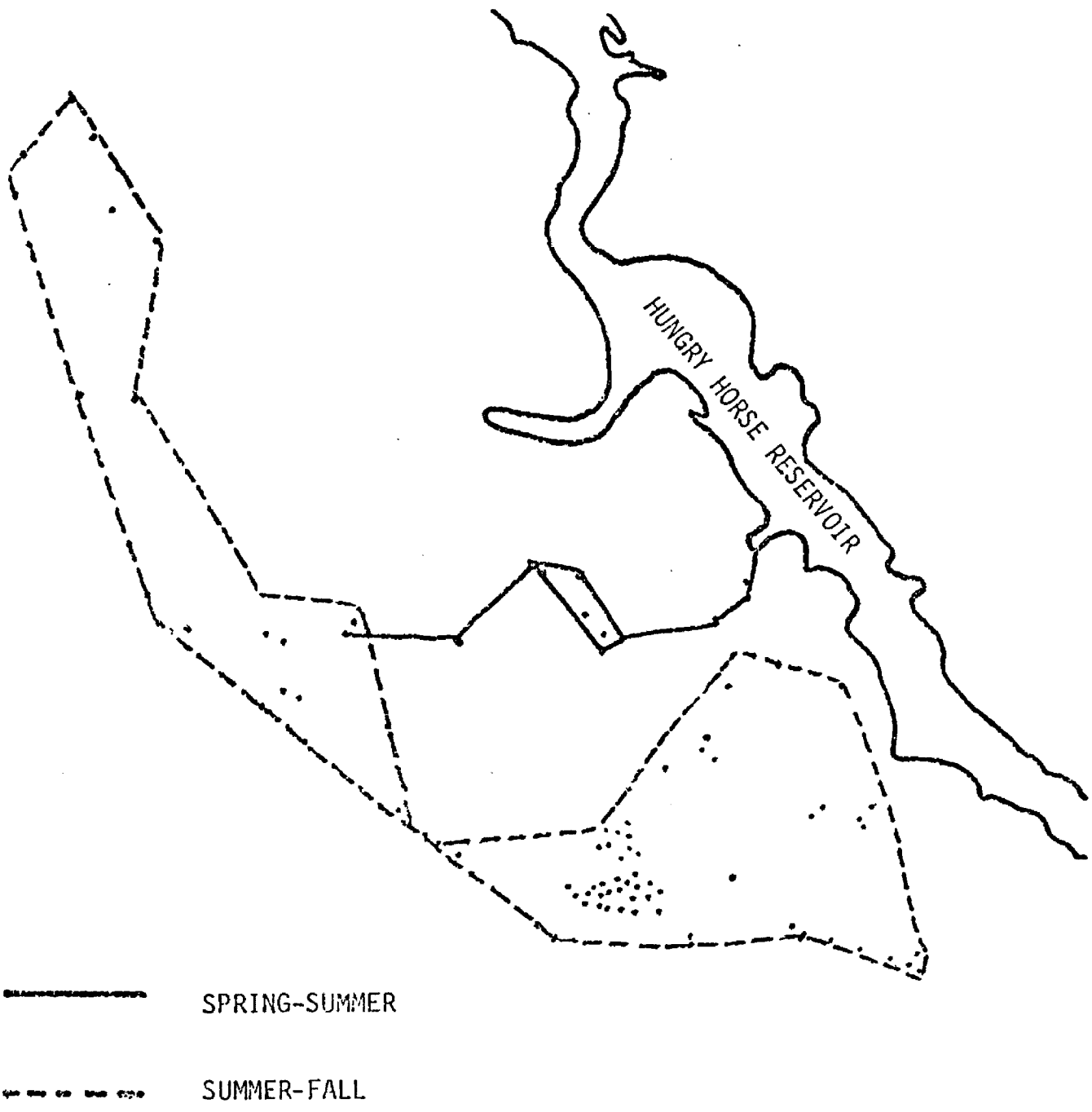


FIGURE 4. SEASONAL HOME RANGES OF MALE GRIZZLY NO. 395, SOUTH FORK OF THE FLATHEAD RIVER, 1979.

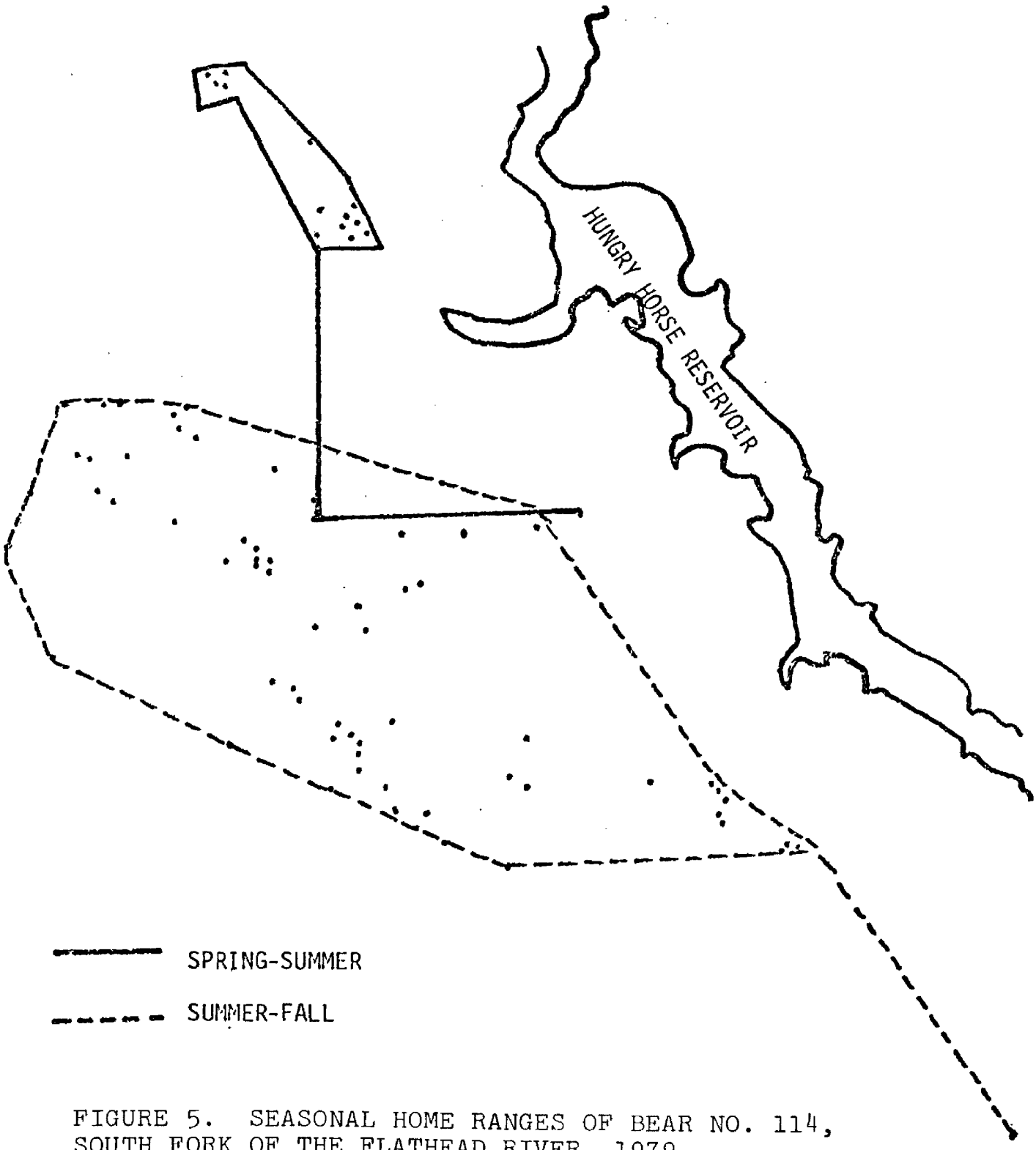


FIGURE 5. SEASONAL HOME RANGES OF BEAR NO. 114, SOUTH FORK OF THE FLATHEAD RIVER, 1979.

Table 2. Areas of home ranges in square kilometers.

Bear Number	Spring-Summer	Summer-Fall	Annual	Days Monitored	No. Locations
297	46.6	82.7	157.5	157	163
363	100.4	120.2	155.4	123	92
395	99.8	144.9	294.8	120	95
114	108.4	226.8	510.7	127	92

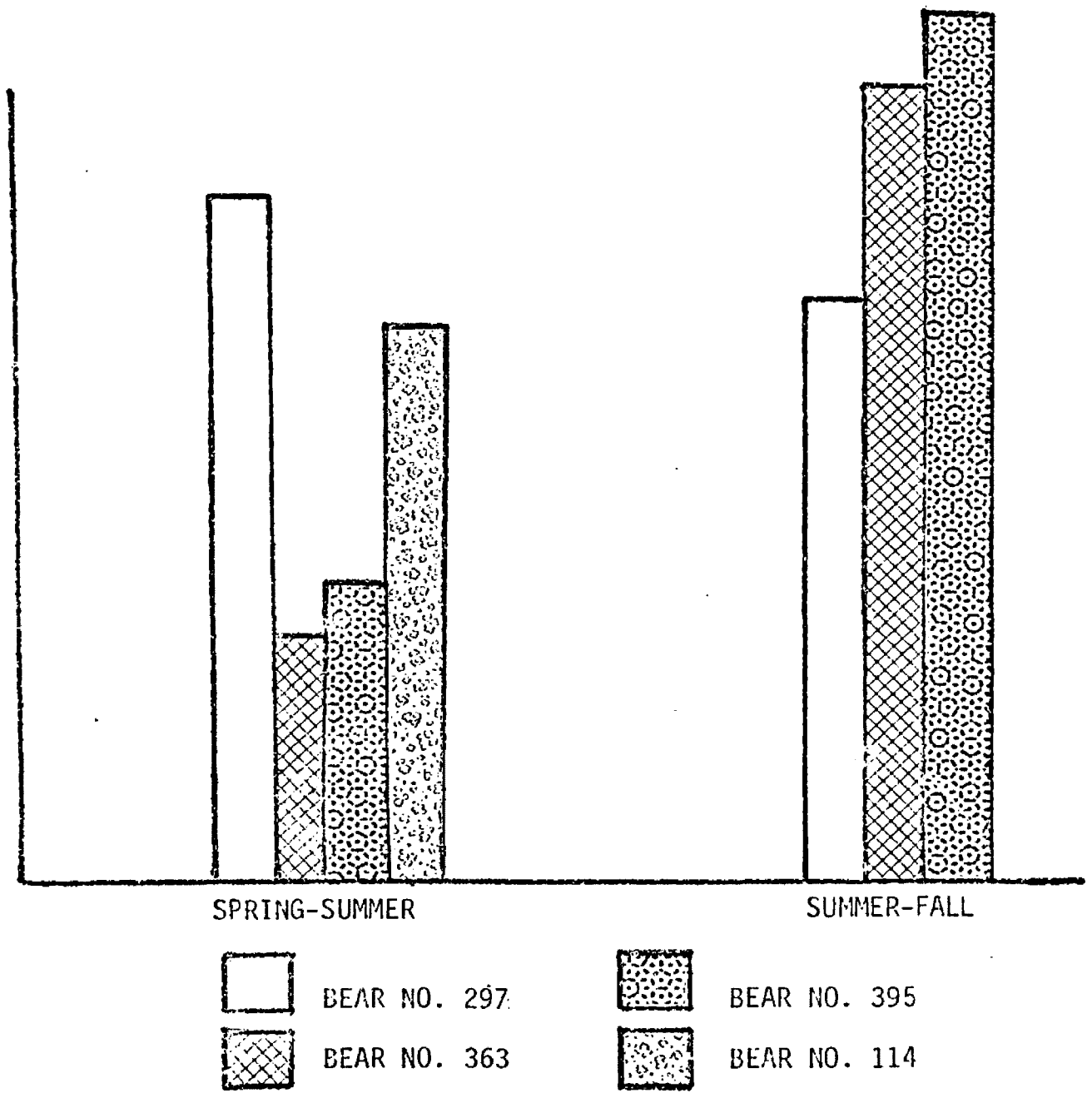


FIGURE 6. SEASONAL MEAN DAILY MOVEMENTS OF GRIZZLY BEARS, SOUTH FORK OF THE FLATHEAD RIVER, 1979.

(at the 0.01 level) than the movements of the younger bears, Nos. 363 and 395. The movements of the younger bears were again not significantly different from each other. Often during the tracking of the older male, No. 114, his movements were of such magnitudes during the summer-fall period that for several days the bear could not be located anywhere in the study area. Therefore, the measured movements of bear No. 114 were not statistically evaluated, but they are believed to be greater than any of the other bears. The summer-fall movements of the younger bears, Nos. 363 and 395, were significantly greater (at the 0.01 level) than their movements during the spring-summer. Female bear No. 297 movements were not significantly different between the seasonal time frames.

Figure 7 shows the movement patterns for individual bears. The spring-summer movement patterns of the younger bears, Nos. 363 and 395, are similar in that only short distances were traveled relative to the other bears. For the same period, the movement pattern of the older male, No. 114, indicates both long and short movements. Bear No. 297, the female with three cubs, had short and mid-range movements. The summer-fall movement pattern of female No. 297 included long-duration, short-distance movements and short-duration, long movements. The movements of the younger bears, Nos. 395 and 363, were erratic, with

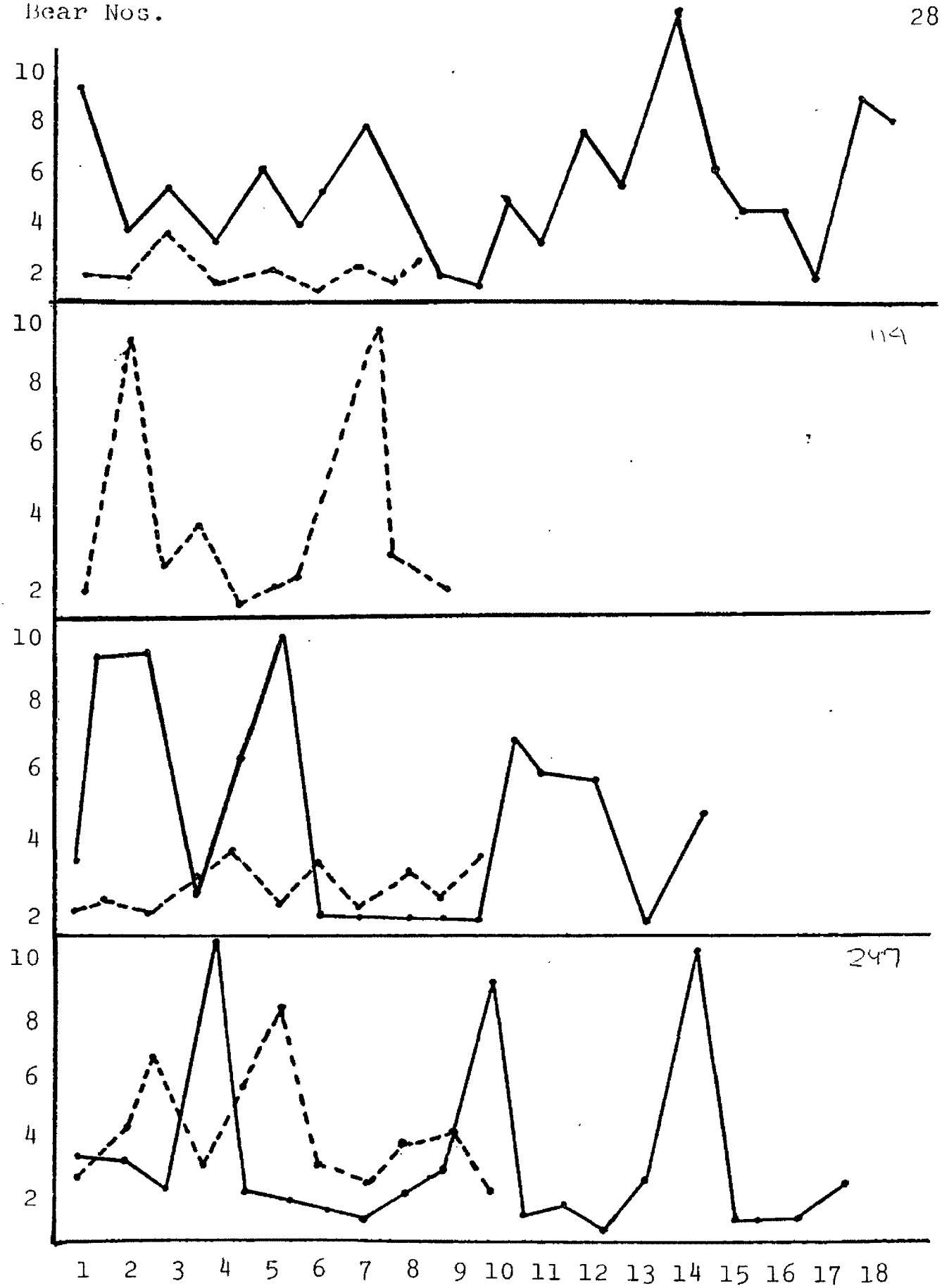
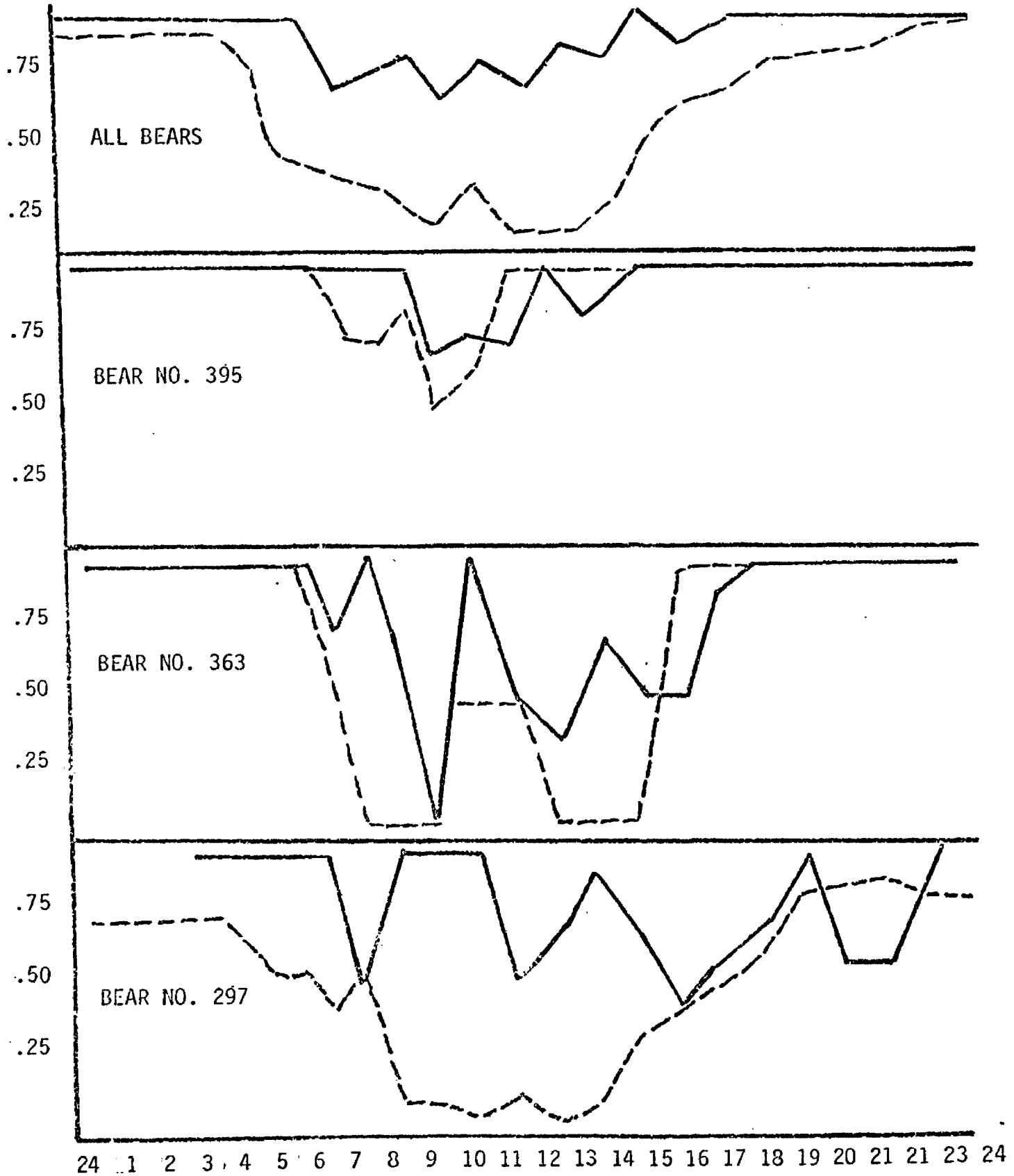


FIGURE 7. SEASONAL MOVEMENT PATTERNS FOR INDIVIDUAL GRIZZLY BEARS, SOUTH FORK OF THE FLATHEAD RIVER, 1979

short-, mid- and long-range movements. Bear No. 395 also had one period of extended, short-range movements. The movement patterns of the older male, No. 114, were not measurable because of an inability to consistently locate him. The data available indicated erratic movements with more long-range movements than the other bears.

Activity Patterns

Figure 8 depicts the activity patterns for the sampled bears. The activity indicates that all bears were more active during the night than during the day (significant at the 0.01 level) for the spring-summer period. During the summer-fall period, no significant difference was found between day vs night activity. All bears were active during all hours of the day. Therefore, the activity of the summer-fall period was significantly greater (at the 0.01 level) than the activity of the spring-summer period. The activity patterns of bears Nos. 363 and 297, the younger female and the older female with cubs, were not significantly different from one another during either the spring-summer or summer-fall periods. The younger male, No. 395, was more active (significant at the 0.05 level) during the daylight hours than bears Nos. 363 and 297 during the spring-summer period, but his activity was not significantly different during the summer-fall period. Bear No. 114 was



ℓ PATTERNS OF INDIVIDUAL GRIZZLY BEARS, SOUTH
\D RIVER, 1979.

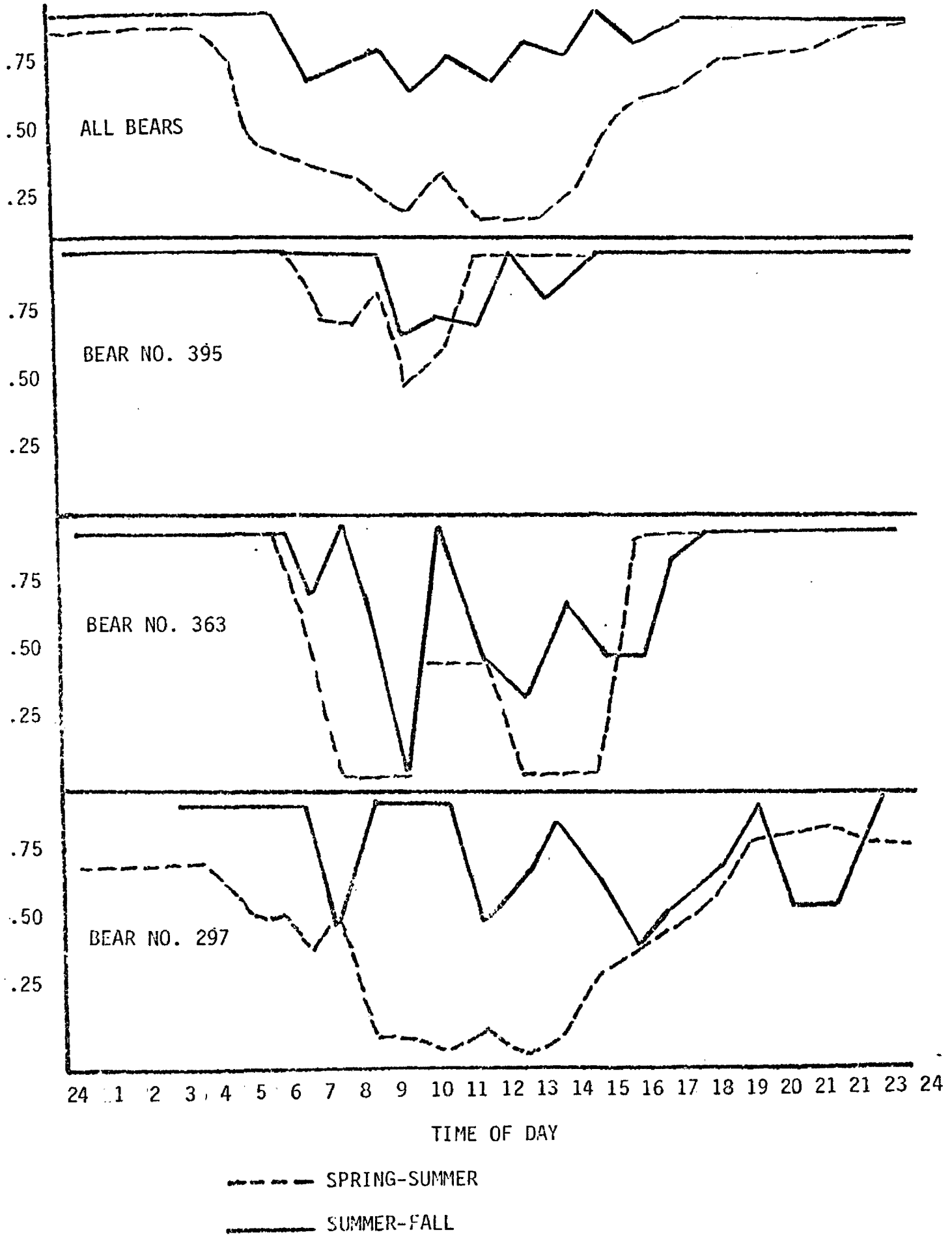


FIGURE 8. ACTIVITY PATTERNS OF INDIVIDUAL GRIZZLY BEARS, SOUTH FORK OF THE FLATHEAD RIVER, 1979.

not included in this set of analyses because of lack of movement data. During the few periods of long-term monitoring, bear No. 114 was moving at all hours of the day and night during both seasonal time periods.

Food Plants

The results of the chemical analyses and the computed nutritional availability indices are exhibited in Table 3. Primarily, both herbaceous and below-ground plant material (Heracleum lanatum, Angelica spp., Taraxacum spp., Trifolium spp., Equisetum arvense, Graminoids, Osmorhiza occidentalis, Lomatium cous, Claytonia laneolata, and Erythronium grandiflorum) make up the spring-summer diet, while berries (Vaccinium spp., Amelanchier alnifolia, Ribes spp., Cornus spp., Sorbus spp.) constitute the summer-fall diet (Mace and Jonkel 1980). During the 1979 field season, the shift to berries occurred on approximately July 31; hence, the time frames selected for previous and subsequent analyses. The berries were not as productive during 1979 as in past years, and certain sites that had been productive during past years did not produce fruit in 1979 (Martin 1979 and pers. comm.).

The leaf and stem portions of the spring-summer bear foods were higher in protein content, cell content, and nutritional availability before the plants flowered. After the plants flowered, the protein values dropped and the

Table 3. Average chemical composition of selected bear foods[1]

PLANT SPECIES	DESCRIPTION OF PLANT[2]	%PROTEIN	%FAT	%AVAILABLE CARBOHYDRATES	NAI[3]	%CW-CC[4]
Heracleum lanatum	1',cp,nf	28.7	5.92	4.40	1.59	22.52-77.48
	2½',cp,nf	27.2	6.82	5.19	1.60	22.96-77.04
	4',cp,ef,if	20.7	5.45	3.97	1.17	48.07-51.93
	4',f,if	28.8	8.35	5.00	1.78	25.93-74.07
Angelica arguta	cp,nf	11.9	4.60	4.87	.79	23.95-76.05
	cp,if	6.7	4.40	5.03	.59	49.06-50.94
	f,if	22.9	6.78	11.97	1.69	31.23-68.77
Osmorhiza occidentalis	cp,nf	24.7	5.92	5.89	1.45	35.74-64.26
	cp,if	17.4	3.81	4.18	.92	43.25-56.75
	if,f	22.3	7.40	7.32	1.54	35.00-65.00
Taraxacum spp.	cp,nf	20.3	5.94	4.21	1.20	37.88-62.12
	f,if	13.2	7.40	5.43	1.10	24.85-75.15
Trifolium spp.	cp,if	21.9	5.38	6.89	1.32	31.19-68.81
Equisetum arvense	3",cp	21.9	6.36	2.98	1.25	36.66-63.34
	6",cp	17.4	5.39	2.47	.98	37.84-62.16
	1',cp	9.8	3.79	2.01	.53	39.21-60.79
Phleum pratensis	cp,nf	26.4	2.79	3.02	1.39	36.64-63.36
	cp,if	15.4	2.64	3.16	.69	48.00-52.00
Agrostis alba	cp,nf	20.3	2.45	3.00	.81	38.02-61.98
	cp,if	9.4	2.41	3.11	.59	49.23-50.87
Lomatium cous	cp,nf	16.9	7.11	5.40	1.23	34.04-65.96
	if,f,rts	12.1	6.34	16.22	1.52	36.79-63.21
	if,rts	14.4	5.57	31.04	2.01	37.69-62.31
Erythronium grandiflorum	if,f,blbs	20.7	6.59	23.81	2.05	31.87-68.13
	f,if	22.1	6.67	2.35	1.27	26.05-73.95
	blbs,if	12.4	5.57	30.07	1.88	37.69-62.31
Vaccinium globulare	brs	6.9	6.48	42.48	2.24	14.99-85.01
Sorbus sitchensis	brs	12.9	3.27	29.60	1.68	26.04-73.96

1. multiple samples and chemical analysis trials
2. numbers = height of plant, cp = complete plant, f = flowers, if = in flower ef = except flowers, rts = roots, blbs = bulbs, brs = berries
3. NAI = nutritional availability index
4. CW = cell wall, CC = cell content

cell wall content increased. Observations on grizzly bear feeding sites indicated that no specific plant parts were being selected for before flowering, but once flowering had occurred only the flowers were eaten. The flowers had similar chemical compositions and cell content percents to pre-flowering herbaceous plant material. The cellular constituents contributing most to nutritional availability indices of metabolizable energy were the protein and fat components, while the primary contributing constituent for the below ground plant material was the available carbohydrates. The metabolizable energy of the below ground roots and bulbs (estimated by the nutritional availability indices) was as high or higher than the pre-flowering stages and flowers of the other plants.

Values for the computed nutritional availability indices of the spring-summer food plants correspond to the diet Importance Values of the individual plants (Mace and Jonkel 1980). Plants of higher nutritional value comprise the major percentage of the diet, except for graminoids and root and bulb producing plants. The graminoids, second only to Heracleum lanatum in diet importance, have a relatively low nutritional availability index, and the root and bulb food plants that comprise a very low percent of the diet have a relatively high nutritional availability index.

Vaccinium globulare comprised three-fourths of the summer-fall diet (Mace and Jonkel 1980) and had the highest nutritional availability index of any of the plants sampled. Available cellular carbohydrates were the highest contributing source of energy for the berry species. Berries other than Vaccinium were only a minor component of the summer-fall diet.

The percent cell contents of the sampled plants corresponded in a relative manner to the values of the computed nutritional availability indices (i.e., the higher the cell content the higher the nutritional availability). The only exception was the percent cell content of Equisetum arvense, which did not decline as the plant grew in height and matured.

Energy Costs

Table 4 contains the computed energy costs for individual bears. Female bear No. 297 had the highest absolute and relative (kcal/kg body weight) energy costs of the individual bears during the spring-summer period. The energy cost of lactation alone during this period was as great or greater than the maintenance costs of the other bears. Weight loss computed for bear No. 297 during the denning period was 63 kg, or 46% of her body weight, due to costs of lactation and hibernation. During the spring-summer period she lost 29 kg, or 39% of her estimated den emergence

Table 4. Computed energy costs of the individual bears.[1]

	Bear Numbers			
	297	363	395	114
Spring-Summer				
Total Maintenance Costs	176,443	206,280	169,840	295,487
Total Milk Production Costs	277,646	0	0	0
Total Energy Costs	454,089	206,280	169,840	295,487
Total Energy Costs/kg body wt.[2]	6,220	2,947	3,145	2,615
Summer-Fall				
Total Maintenance Costs	242,234	222,542	183,147	318,766 (335,089)[3]
Fat Production Costs	828,000	157,500	121,500	254,700 (414,000)
Total Energy Costs	1,070,234	380,042	304,647	543,468 (749,089)
Total Energy Costs/kg body wt.	14,661	5,429	5,642	5,075 (6,629)

[1]Energy costs expressed in kcal/seasonal period.

[2]Body weight at beginning of time period.

[3]Computed using late fall capture weight.

weight of 73 kg through lactation. From den entry to the end of the spring-summer period, bear No. 297 lost an estimated 92 kg, or 67% of her body weight. The computed absolute energy costs of the older male, No. 114, were higher than for the young bears, Nos. 363 and 395, while the relative energy costs of the younger bears were higher. The computed energy costs of the two smaller bears were similar to each other.

Total energy costs during the summer-fall period were greatest for female No. 297 by a multiple of three compared with the energy costs of the other bears. Except when compared to the estimated energy costs of male No. 114, costs of female No. 297 were greater by only a multiple of 0.3. The energy costs of the younger bears were again similar. The energy costs of all bears were greater for the summer-fall period than the spring-summer, apparently because of the energy cost of fat production.

The energy, as well as the protein requirements of body frame growth, were not computed for the individual bears. A lack of body growth constants and assimilation information precluded analyses for this parameter. Kingsley et al. (In Press) reported on the growth in body length of young grizzlies of age similar to the younger bears, Nos. 363 and 395. If bears Nos. 363 and 395 were still growing, their computed energy costs were underestimated for both seasonal time periods.

DISCUSSION

The general behavioral patterns and energy requirements for any species determine their space or range requirements. This range requirement is a dynamic entity that varies with daily rhythms, seasonal rhythms, and climatic conditions at a particular time (Moen 1973). The home range size of an individual is determined by several factors, including its energy requirements for a particular time, how intraspecific and interspecific (including man) interactions impose behavioral constraints on the abilities of the individual to meet its energy costs, and the availability and distribution of food stuffs within that animal's geographic area. The movements of an individual within its home range are also dependent on the individual animal's energy and behavioral requirements and are influenced strongly by the distribution of food or habitat components contained in its home range. The gross arrangement of habitat components is to a degree inherent to an area because of climatic and other environmental and physical features. However, fine differences in habitat component distribution or diversity are evident, and therefore selection by an individual for a particular habitat mosaic that best suits its needs and abilities is advantageous.

The seasonal selection of food species within a mosaic of habitat components is determined by the availability, nutrient content, digestibility, and the palatability of food species. Consequently, one would expect to find

varying home range sizes, movement patterns, habitat selection patterns, and food habits for individuals of differing energy and behavioral requirements. Such differences were evident for the four grizzly bears radio-tracked in the South Fork Study Area.

Spacial overlap of grizzly bear home ranges has been documented by Pearson (1975), Craighead (1976), Nagy and Russell (1978), and Russell et al. (1979). The results of this study concur with other authors except for the lack of overlap displayed by female No. 297 (Fig. 1). This non-overlap was apparently related to a lack of information on other bears in the area rather than a real difference. Grizzly bear tracks and scats were recorded within the computed annual home range of bear No. 297 (BGP files). This recorded sign did not indicate temporal overlap, whereas both temporal and spacial overlap was noted for the home ranges of the other bears (Mace et al. 1980).

My computed annual home ranges agree with the findings of Pearson (1975), Nagy and Russell (1978), and Russell et al. (1979) in that the older male exhibited the largest home range, followed by the subadults and the females with young (Table 2).

During the spring-summer period, the home range of the older male, No. 114, was similar in size to the ranges of the younger bears, Nos. 363 and 395. The above researchers reported extensive movements by older, adult

males during the breeding season,producing large spring-summer home ranges. The comparable range for male No. 114 during this period was probably related to the lack of radio locations during the early spring (No. 114 was not radio instrumented until June 22). Craighead et al. (1969) reported that the breeding activity of Yellowstone grizzlies peaked during the first 2 weeks of June, and post copulatory behavior (limited search for females) extended to the middle of July. If similar breeding patterns prevail on my South Fork Study Area, only the later portion of the breeding activities of bear No. 114 were measured.

Pearson (1975) postulated that females contract their home range when accompanied by young of the year. Furthermore, Pearson (1975) and Russell et al. (1979) stated that during the spring and early summer months females with cubs actively avoid adult males, utilizing as rugged and isolated terrain as possible,with escape routes into even rougher terrain. The area utilized by female No. 297 and her three cubs was proximal to the higher elevations in the Swan Mountains of the South Fork Study Area, an area that is both rugged and isolated.

Although the measured movements of the older female, No. 297, and male, No. 144, were similar in magnitude for the spring-summer period (Fig. 6), their movement patterns (Fig. 7) and home range sizes (Table 2) indicate different

utilization patterns. The long- and short-range movements of bear No. 114 over a large area differ from the mid- and short-range movements of female No. 297 in a smaller area. The high level of movements of bear No. 297 in a small area suggests concentrated use of the entire area, while the movements of bear No. 114 indicate utilization of major portions of his home range for travelling purposes, perhaps for mates, and only a small percent for intensive feeding. The short-range movements (Figs. 6-7) by bears Nos. 363 and 395 within the spring-summer home ranges, which were as large as the area of the older male, No. 114 (Table 2), may indicate selective feeding habits, concern for energy conservation, and/or exploratory behavior.

The lower berry production during 1979 may have altered the movements of the sampled bears during the summer-fall period. A lack of comparable data on the South Fork Study Area during a "normal" berry production year precluded evaluation of their movements to be the norm or the exception. Pearson (1975) reported no shifts in grizzly bear home ranges in response to berry crop failure, whereas Amstrup and Beecham (1976) reported increased movements by black bears during a year of reduced food supply.

In accordance with the above, the measured movements of female No. 297 during the summer-fall did not vary significantly from the spring-summer period, but her patterns of movement did. This indicated short-range

movements (Fig. 7) over long periods that were concentrated in and around one particular berry producing area (BGP files). The few long-range, short-duration movements of female No. 297 were to other berry production sites that were productive in past years (Martin 1979 and Pers. Comm.). During 1979 these sites were not productive, and female No. 297 visited them briefly, then returned to her previous locale. Even though her long-range movements made her summer-fall home range size greater than her spring-summer area, female No. 297 did not continue seeking alternate feeding sites to the degree of the other bears. The younger male, No. 395, spent considerable time in one particular area as displayed by the one period of short-range movements in Figure 7. However, his other movements and his larger home range (Table 2) indicated extensive movements to alternate feeding areas. The greater movements and larger home range sizes of the other bears, Nos. 114 and 363 (Figs. 6 and 7, Table 2), also indicate a greater ability by these bears to seek alternate feeding areas. Pearson (1975) reported random movements by grizzly bears during periods of berry availability, except for females with cubs.

Varied activity patterns have been reported for grizzlies in their use of habitat. Pearson (1975) reported that daily activity levels of grizzlies did not alter between seasonal periods, with the main daily activity periods occurring in early morning, late afternoon, and night.

Brown bears (also Ursus arctos) of southeastern USSR were reported to be primarily diurnal during the early spring and to become more nocturnal as summer approaches (Bromlei 1965). Craighead and Craighead (1965) also attributed nocturnal activity to the grizzly bear in Yellowstone National Park. Similar variations have been reported in black bear activity patterns.

Garshelis and Pelton (1980) reviewed black bear activity and through the use of activity sensors found black bears in the Great Smoky Mountains exhibiting a crepuscular activity rhythm that was modified seasonally by mating activity and by changes in the type and abundance of foods. They reported crepuscular activity to be most distinct during spring, and attributed this to a limited availability of nutritious foods. Great Smoky Mountain black bears were most active during the breeding season and during periods of berry availability. However, the activity of females with cubs did not vary seasonally and they were the most active of any age-sex group.

Variation was noted in this study among individual bears and between the seasonal time frames. The activity of female No. 297 during the spring-summer period was limited to the nighttime hours, even though her movements during this period were relatively great compared to the other bears. The nature of her movements, as previously

discussed, perhaps precluded daylight activity for security of her cubs. The limited daylight activity of the younger female, No. 363, during the spring-summer period, perhaps was related to energy conservation, while the greater daylight activity of the males, Nos. 114 and 395, may have been related to breeding activity. All bears were more active during the summer-fall period than during the spring-summer months. This increased activity was attributed to the availability of a more nutritious food source (i.e., berries) and the need of bears to acquire the necessary weight gains for hibernation.

Results similar to mine have been reported by Mealey (1975), Hamer et al. (1977 and 1978), Bumgarner (1979), and Lloyd (1979) for equivalent chemical analyses of bear plant foods. Those authors also reported a decline in the nutritional value of herbaceous plant material as the plants matured. Mealey (1975) gave much higher digestibility estimates and nutritional index values than my results. The proximate analysis procedure used by Mealey for chemical composition analysis determinations, in conjunction with direct comparisons of scat material for digestibility estimates, is believed to have caused the difference in results. Proximate analysis does not produce distinct nutritional categories (Crampton and Harris 1969, Van Soest 1978) for energy assessments, and the direct scat comparisons for digestibility estimates has many inherent problems

(Crampton and Harris 1969, Hamer et al. 1977).

Even though early stages of the herbaceous plant foods are of relatively high nutritional value, the temporal availability of nutrients is limited because of rapid loss of nutrients and digestibility as the plants grow. Based on the comparisons of the nutritional availability indices with the diet Importance Values (Mace and Jonkel 1980) of the bear plant foods, the food selection appears to be governed by nutrient content and digestibility as well as by availability; i.e., graminoids are of high diet importance and relatively low nutritional value but are the most available food source during the early spring (Joslin et al. 1977). Conversely, the low utilization of the root and bulb food plants (both of high nutritional value) is perhaps related to their low availability (Joslin et al. 1977).

The habitat selection reported by Zager et al. (In Press) indicated use of the slabrock habitat component by female No. 297 during the later portion of the spring-summer period (July) and by all bears during the summer-fall period. (For physical and vegetative descriptions of the BGP grizzly bear habitat components refer to Mace et al. 1980). The slabrock habitat component contained root and bulb food plants (Lomatium spp., Erythronium grandiflorum, and Claytonia lanceolata), all utilized by grizzlies. Also, grizzly bear dig sites for Erythronium grandiflorum and

Lomatium cous were found within the home range of female No. 297 (BGP files). The utilization of the slabrock habitat component by female No. 297 and her three cubs during the month of July was possibly influenced by her high energy costs, her low body weight (Table 4), and the lower digestibility and nutritional values present in the matured herbaceous plant material. Utilization of the slabrock component by all bears during the summer-fall period may have been related to the poor berry production of 1979; i.e., the root and bulb plant foods functioned as an alternate food source not normally utilized because of its lower availability compared to the berry producing species (Joslin et al. 1977). Pearson (1975), Hamer et al. (1977), and Russell et al. (1979) reported utilization of Hedysarum spp. roots during periods of low berry availability.

The nutritional value of Equisetum arvense decreased as it grew in height, but the digestibility did not alter significantly (Table 3). The nutritional value of the early stages of Equisetum arvense, a major constituent of the creek bottom habitat component (Mace and Jonkel 1980), and its constant digestibility, make it an important food source during the spring-summer period and an alternate food source during the summer-fall, as evidenced by the utilization of the creek bottom habitat component during both seasonal periods by all of the radio instrumented bears (Zager et al. In Press). Hamer et al. (1977 and 1978)

reported utilization of Equisetum spp. by grizzly bears from May through August.

Through the use of feeding trails, grizzly digestibility of Vaccinium spp. berries was estimated to be 88% (Hamilton 1978 cited in Lloyd 1979). Lloyd (1979) also reported the metabolizable energy of Vaccinium spp. berries to be approximately 2.8 kcal/g. Both values correspond favorably to the results of my study (Table 4). Vaccinium globulare fruit had the highest nutritional value and digestibility of any of the plant foods analyzed (Table 4), and it was the major constituent of the summer-fall grizzly diet (Mace and Jonkel 1980). The importance of berries as a super-abundant, high quality food for weight gain and successful reproduction has been documented by Jonkel and Cowan (1971) and Rogers (1976).

During the spring-summer period, bears used primarily snowchute and creek bottom habitat components, and (as noted) female No. 297 also used the slabrock component. Habitat components used by all bears during the summer-fall period were, primarily, timbered shrubfields, creek bottoms, and slabrock. Zager et al. (In Press) reported proportionately equal availability of habitat components in each of the annual home ranges of the four bears. Consequently, the smaller the home range area utilized, the more diverse the area in habitat components.

Pearson (1975) postulated that females with young

selected a core area of their home range that best suited their food and behavioral requirements. The relative and absolute energy costs of female No. 297 far exceeded the costs of the other bears. The smaller, more diverse,and isolated home range of female No. 297 was more heavily utilized than the larger, less diverse ranges of the other bears. The protective behavior of No. 297 for her cubs, and her relatively high energy costs,indicated strong influences on her home range size, site selection, utilization patterns, alternate food habits, and habitat selection. The lack of movement to alternate feeding sites by female No. 297 during the summer-fall period again was possibly influenced by her protective behavior for her cubs. Also, if her weight loss estimates were accurate during the spring-summer period (similar weight losses have been reported by Jonkel (1967), her body fat level may have been depleted to such a degree as to preclude movements to alternate feeding sites.

The younger bears, Nos. 363 and 395, had relative energy costs that were less than those of female No. 297 and greater than the older male, No. 114, particularly if the energy costs of body frame growth are considered. Pearson (1975) suggests that young females gradually expand their home range size through exploratory behavior until the time when they produce young. At that time they select the most suitable area as a core area for cub rearing.

Conversely, younger males apparently expand their home range areas through exploratory behavior to encompass more females, and thereby enhance their breeding potential. The short range movements of the younger bears, Nos. 363 and 395, over a relatively large area during the spring-summer period indicated not only exploratory behavior, but possibly selective foraging to meet their maintenance and growth requirements. Short-range movements and selective feeding habits should logically conserve energy and thereby better facilitate utilization of the higher protein content of the most succulent herbaceous plant materials. Also, by conserving energy during the spring-summer period, greater movements would be possible during the summer-fall to select the most productive berry patches and to further expand home range areas.

The growth curves of Kingsley et al. (In Press) indicate that male bears progressively gain weight from one spring period to the next and one fall period to another (excluding gross fluctuations in weight caused by berry crop failure). Therefore, when an older male emerges from the den, fat is present to supply the necessary energy for the extensive movements associated with breeding activity. Also, the lower relative energy cost and greater fat levels characteristic of males facilitate extensive movements to alternate feeding sites during the summer-fall period. The movements and home range sizes of the older male,

No. 114, exemplified such an ability for extensive movements.

Based on the growth curves available (Kingsley et al. In Press and Beecham unpublished data), the computed energy costs, and the lower nutritional value of the spring-summer foods, the ability of a bear to meet the energy costs of its life processes during the spring-summer period is closely linked to the condition of the animal when it emerges from the den. The paucity of nutritious foods and the high energy costs of lactation, growth, or breeding activity during the spring-summer period dictate the utilization of body fat to supplement the energy acquired through foraging. Therefore, during the period of berry availability, the individual animal must not only gain sufficient weight to survive hibernation, but also additional weight to help meet the energy demands of the spring-summer period. Conversely, if adequate energy is not obtained during the spring-summer period, weight loss may be too great for adequate weight gains during summer-fall to allow hibernation and reproduction activities.

Management Recommendations

If females, through protective behavior for their young combined with the high energy costs of lactation, are selecting and intensively utilizing diverse core areas as suggested by Pearson (1975), efforts should be made to reduce disturbances in areas known to be inhabited by females of reproductive age. Through additional studies

on habitat utilization patterns of females with young, their mosaic habitat structure may be further delineated as possible Critical Sites (Zager et al. 1980).

The limited availability of nutritious foods, the high energy costs associated with lactation and growth, and the extensive movements associated with breeding activity of the spring-summer period, create a situation in which disturbance may be especially detrimental. Grizzlies have few alternate feeding areas during the early spring and summer months because of continued snow cover on most of their range. The food plants at that time are present in snowchute and creek bottom habitat components (Mace et al. 1980). Disturbances to these areas and areas proximate to them should be avoided, particularly during the time of grizzly use. Travel corridors must also be maintained to facilitate movement to other such sites by breeding males and possibly by younger males extending their home range or selecting highly succulent, nutritious foods.

The creek bottom and slabrock habitat components that function as alternate feeding sites during the summer-fall period should also be protected from disturbances, as well as areas adjacent to them. The slabrock component, because of highly nutritious root and bulb producing plants and its possible importance to females with young during the spring-summer period, should receive special attention. The low commercial timber value of the slabrock component may preclude

disturbances to the site, but areas proximate to it must be maintained for cover and travel purposes.

During the summer-fall period, grizzlies must obtain sufficient food to replenish the weight lost during denning and early spring-summer periods. Sites that remain constantly productive for Vaccinium spp., even during low rainfall periods, must be identified, protected, or created.

The above research was conducted during only one field season of radio tracking four individual bears. To fully describe and delineate grizzly bear habitat, utilization patterns, and energy requirements, similar long-term studies of grizzly energetics must be conducted.

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APPENDIX I

ELLIPTICAL HOME RANGE BASIC COMPUTER PROGRAM

Input data are paired X and Y coordinates obtained from a grid overlay of the base map containing the radio locations. Each line of the data file contains the X and Y coordinate pairs for one radio location point. The name of the data file is placed on line number 5. The multiplication factor contained on line number 121 must be equivalent to the area (km^2) of one grid unit compared to the base map. Formulas used are from Jennrich and Turner (1969).

```
 5 FILES (NAME OF DATA FILE)
10 RESTORE #1
15 PRINT "INPUT NUMBER OF LOCATIONS (L)";
16 PRINT
17 PRINT
20 INPUT L
25 S = 0
30 T = 0
35 FOR J = 1 TO L
40 INPUT #1,X,Y
45 S = S + X
50 T = T + Y
55 NEXT J
60 S = S/L
65 T = T/L
66 V1 = 0
67 V2 = 0
68 V = 0
69 RESTORE #1
70 FOR I = 1 TO L
75 INPUT #1,X,Y
80 V2 = (Y - T) ** 2 + V2
85 V1 = (X - S) ** 2 + V1
90 V = (X - S) * (Y - T) + V
```

```
 95 NEXT I
100 V1 = V1/L-2
105 V2 = V2/L-2
110 V = V/L-2
115 S = ABS ((V1*V2) - (V**2))
120 A4 = 6 * 3.14 * (S**.5)
121 A4 = A4 * .0072873
125 PRINT "AREA OF HOME RANGE AT 95% LEVEL"
130 PRINT "          ";A4"SQ. KILOMETERS"
135 END
```

APPENDIX II

LINEAR DISTANCES BETWEEN CONSECUTIVE LOCATIONS

Distances were measured from the first location of a day to the first location of the following day.

Bear Number	Season	Distance (km)
297	Spring-Summer	0.3
		1.1
		1.1
		9.3
		4.9
		2.9
		3.0
		7.4
		7.2
		4.7
		0.2
		2.2
		1.5
		5.1
		8.7
		3.1
		7.1
		10.8
		4.0
		2.5
		4.6
		5.0
		1.8
	Summer-Fall	3.2
		3.0
		1.9
		22.2
		2.2
		1.7
		1.8
		0.8
		1.2
		3.2
		10.2

Bear Number	Season	Distance (km)
297 (Cont'd.)		0.8
		1.2
		0.4
		5.3
		15.0
		0.8
		0.6
		0.8
		2.3
		2.5
		2.5
		1.2
		1.2
		3.1
		2.1
		16.7
		5.1
		18.1
		3.9
		0.3
		0.5
		0.7
		9.2
		3.0
		5.9
		1.9
		1.4
363	Spring-Summer	0.8
		0.8
		3.8
		1.4
		1.7
		1.4
		1.4
		1.7
		1.3
		2.4
	Summer-Fall	9.6
		3.8
		5.5
		3.2
		6.5
		3.8

Bear Number	Season	Distance (km)
363 (Cont'd.)		5.9
		8.3
		1.7
		0.2
		4.7
		3.0
		7.2
		5.5
		12.8
		5.3
		3.3
		3.5
		1.2
		8.0
		7.4
		3.5
		11.2
		5.8
		0.7
		0.3
		1.0
		2.1
		13.2
		6.0
395	Spring-Summer	0.7
		0.7
		0.3
		0.6
		2.5
		4.3
		1.0
		3.4
		3.0
		3.7
	Summer-Fall	3.1
		12.2
		12.1
		1.9
		7.2
		12.5
		0.4
		1.1
		0.4

Bear Number	Season	Distance (km)
395 (Cont'd.)		0.5
		0.4
		8.1
		6.4
		6.5
		0.6
		4.2
114	Spring-Summer	0.6
		13.4
		3.2
		4.2
		0.2
		1.5
		2.2
	Summer-Fall	6.5
		7.8
		6.5
		6.8
		3.7
		7.8
		1.6
		1.1
		1.7
		0.3
		5.6
		0.8
		2.5
		7.4
		4.2

APPENDIX III

ACTIVITY RECORDINGS OF INDIVIDUAL BEARS

Time of Day	Spring-Summer		Summer-Fall	
	Movement[1]	Stationary	Movement	Stationary
Bear No. 297				
1	3	1	2	0
2	3	1	3	0
3	3	1	2	0
4	3	1	3	0
5	2	1	1	0
6	1	1	2	0
7	2	2	2	0
8	2	3	1	0
9	5	3	2	2
10	1	4	3	0
11	1	4	3	0
12	1	6	3	0
13	1	4	1	1
14	0	4	3	1
15	1	5	4	1
16	3	5	3	1
17	2	3	2	3
18	3	3	2	2
19	4	3	2	1
20	6	1	3	0
21	7	1	1	1
22	6	1	3	0
23	3	1	2	0
24	3	1	3	0
Bear No. 363				
1	2	0	1	0
2	2	0	2	0
3	3	0	1	0
4	2	0	3	0
5	2	0	2	0
6	3	0	2	0
7	4	0	1	0
8	1	1	2	1
9	0	0	2	0
10	0	0	2	1
11	3	0	0	2

Time of Day	Spring-Summer		Summer-Fall	
	Movement	Stationary	Movement	Stationary
Bear No. 363 (Cont'd.)				
12	2	2	1	0
13	1	1	1	1
14	0	3	1	2
15	0	3	3	1
16	0	3	3	3
17	1	0	2	2
18	2	0	6	1
19	1	0	2	0
20	3	0	2	0
21	2	0	3	0
22	3	0	3	0
23	2	0	4	0
Bear No. 395				
1	3	0	3	0
2	4	0	2	0
3	2	0	2	0
4	4	0	1	0
5	3	0	2	0
6	2	0	2	0
7	3	0	1	0
8	3	0	2	1
9	4	0	4	2
10	2	0	4	1
11	2	1	2	3
12	4	1	2	2
13	3	1	3	0
14	2	0	3	0
15	2	0	4	2
16	4	0	5	0
17	2	0	3	0
18	4	0	3	0
19	3	0	4	0
20	2	0	2	0
21	3	0	1	0
22	3	0	2	0
23	2	0	3	0
24	1	0	2	0
Bear No. 114				
1	1	0	3	0
2	0	1	0	0

Time of Day	Spring-Summer		Summer-Fall	
	Movement	Stationary	Movement	Stationary
Bear No. 114 (Cont'd.)				
3	0	0	3	0
4	0	0	3	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	1
9	0	0	0	1
10	1	1	0	1
11	0	0	0	0
12	0	0	0	0
13	1	3	0	0
14	0	4	3	0
15	2	1	1	0
16	0	0	1	0
17	0	0	1	1
18	1	1	1	1
19	1	0	0	1
20	1	0	0	1
21	1	0	0	0
22	1	0	0	0
23	0	0	1	0
24	0	0	0	0

[1]Number of times bears were recorded as moving or stationary.